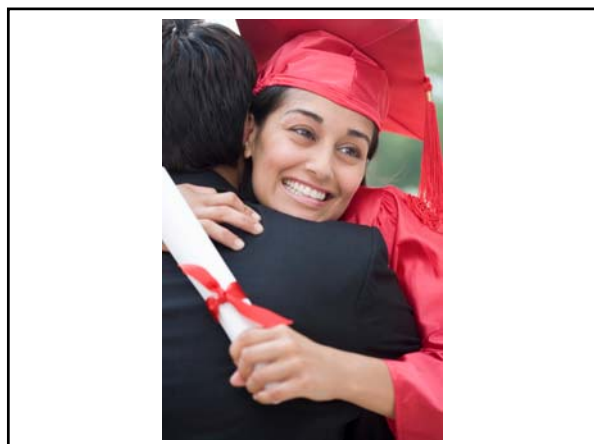




Level 3 Competency Exam

- See booklet
- Also on ChE web page
 - Undergraduate page

Last but not least...

- **Counting today**
 - 4 more class periods, including
 - 2 classes on Energy balances
 - 1 class on transient balances
 - Review for Exam 3... then Exam 3
 - Case Study (Ch. 14 problems)
 - Review for Final Exam
 - Final Exam



The End is Near!!

Goals Today

1. Energy Balance with ΔH_r^0 (single rxn)
2. Energy Balance with ΔH_f^0 (multiple rxns)



1. Energy Balance with only One Reaction

Board Problem
 $A \rightarrow bB$



Path method, incomplete conversion

Caution on Enthalpy Tables

Find $\hat{H}_{H_2O, liq}$ at 25°C, 1 atm

1. Use steam tables (Table B.5)
 $(104.8 \text{ kJ/kg})(\text{kg}/1000 \text{ g})(18 \text{ g/mol}) = 1.886 \text{ kJ/mol}$
 sat'd liquid (0.0317 bar)
2. Use ΔH_f^0
 Table B.1 says $\Delta H_f^0 = -285.84 \text{ kJ/mol}$ at 25°C and 1 atm

What about VdP term since reference for steam tables is at 0.0317 bar?

$$\begin{aligned} V_{\Delta P} &= (0.00101 \text{ m}^3/\text{kg})[1 \text{ atm} - 0.0317 \text{ bar}(\text{atm}/1.01325 \text{ bar})](1.01325 \text{e}5 \text{ N/m}^2/\text{atm}) \\ &= (99.1 \text{ N-m/kg})(\text{kg}/1000 \text{ g})(18 \text{ g/mol})(\text{J/N-m})(\text{kJ}/1000 \text{ J}) \\ &= 1.78\text{e-}3 \text{ kJ/mol} \quad (\text{not enough to make a difference}) \end{aligned}$$

Bottom line: Do not mix and match enthalpies from different tables!

Look at Table B.7

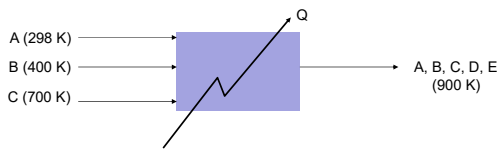
- How does $\hat{H}_{\text{liq water}}$ change with pressure at 50°C? (use steam tables)
 - 0.5 bar → 209.3 kJ/kg
 - 1.0 bar → 209.3 kJ/kg
 - 5.0 bar → 209.7 kJ/kg (0.19% above 0.5 bar value)
- Pretty small change!! (for a liquid)
 - But relatively small change in pressure
- What about for steam?
 - At 350°C, $\Delta \hat{H}_{5\text{bar}}$ vs $\Delta \hat{H}_{0.5\text{bar}}$ = 0.28% decrease

2. Energy Balance with Multiple Reactions using ΔH_f°

- Most common approach
- Most reliable approach

$$\Delta H + \Delta E_k + \Delta E_p = Q - \dot{W}_s$$

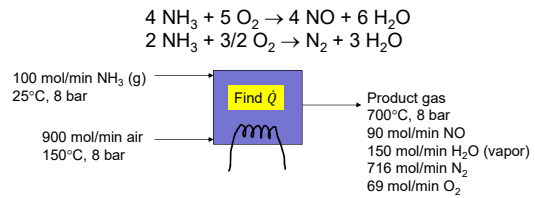
$$\Delta \dot{H} + \Delta \dot{E}_k + \Delta \dot{E}_p = \dot{Q} - \dot{W}_s$$
- $\Delta \dot{H} = \dot{H}_{\text{out}} - \dot{H}_{\text{in}} = (\sum n_i \hat{H}_i)_{\text{out}} - (\sum n_i \hat{H}_i)_{\text{in}}$
- $\hat{H}_i = \Delta \hat{H}_{i,f}^\circ + \int_{T_{\text{ref}}}^T \hat{C}_p dT$



Idea: Construct a Table

In					Out				
Species	n_i	T	$\hat{H}_i$	$n_i \hat{H}_i$	Species	n_i	T	$\hat{H}_i$	$n_i \hat{H}_i$
A	2	298	?	?	A	.5	900	?	?
B	1	400	?	?	B	.1	900	?	?
C	.5	700	?	?	C	.05	900	?	?
D	0	-			D	1	900	?	?
E	0	-			E	1.3	900	?	?

Example: Problem 9.23 (9.20 in 3rd Ed.)



Step 1: Write the mole balance (already done)

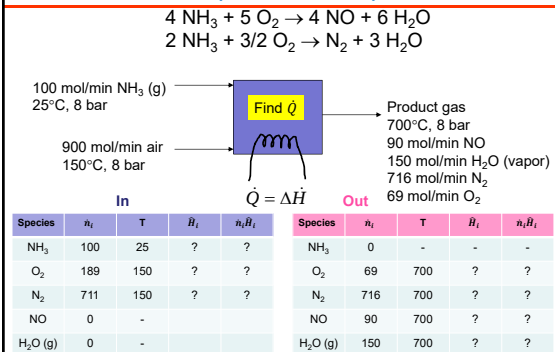
Step 2: Write the energy balance

Energy Balance with ΔH_f°

$$\cancel{\Delta \dot{H}} + \cancel{\Delta \dot{E}_k} + \cancel{\Delta \dot{E}_p} = \cancel{\dot{Q}} - \cancel{\dot{W}_s}$$

- $\Delta \dot{H} = \dot{H}_{\text{out}} - \dot{H}_{\text{in}} = (\sum n_i \hat{H}_i)_{\text{out}} - (\sum n_i \hat{H}_i)_{\text{in}}$
- $\hat{H}_i = \Delta \hat{H}_{i,f}^\circ + \int_{T_{\text{ref}}}^T \hat{C}_p dT$

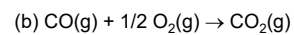
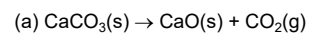
Example: Problem 9.23 (9.20 in 3rd Ed.)



Excel Sheet

Homework: Problem 9.28

(9.23 in 3rd Ed.)

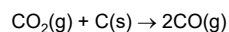


Draw schematic of part (a) to find Q

Draw schematic of part (b) to find new Q

Homework: Problem 9.38

(9.32 in 3rd Ed.)



Draw schematic (given T_{in} , T_{out} , Q, find conversion of C(s))

Hint: use ξ to solve for moles of outlet species so that energy balance is only a function of ξ . Use solver to find ξ , then calculate conversion (X_C).

Homework: Problem 9.63

(9.56 in 3rd Ed.)

Draw schematic

